B&W Y-12, l.l.c. RCO/TBD-097, Rev. 0
RADIOLOGICAL CONTROL ORGANIZATION
TECHNICAL BASIS DOCUMENT

Results from 2010 Caliban Criticality Dosimetry Intercomparison

October 11, 2011

Results from 2010 Caliban Criticality Dosimetry Intercomparison

Prepared by:	K.G. Veinot /s/	10/12/2011
	K.G. Veinot	Date
Reviewed by:	M.L. Souleyrette /s/	10/12/2011
	M.L. Souleyrette	Date
Approved by:	R.S. Bogard /s/	10/12/2011
	R.S. Bogard Dosimetry and Records Manager	Date

Prepared by the
Radiological Control Organization
Y-12 National Security Complex
operated by
B&W Y-12
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR-22800

DISCLAIMER

COPYRIGHT NOTICE

Contents

List of Tables

List of Figures

1 Introduction

The external dosimetry program participated in a criticality dosimetry intercomparison conducted at the Caliban facility in Valduc, France in 2010. Representatives from the dosimetry and instrumentation groups were present during testing which included irradiations of whole-body beta/gamma (HBGT) and neutron thermoluminescent dosimeters (TLDs), a fixed nuclear accident dosimeter (FNAD), electronic alarming dosimeters, and a humanoid phantom filled with reference man concentrations of sodium. This report reviews the testing procedures, preparations, irradiations, and presents results of the tests.

2 Facility Description

The Caliban reactor is located at the CEA Valduc Center in Is-sur-Tille, France. Cylindrical in shape, its diameter is 19.5 cm and its height is 25 cm. It is composed of two blocks: a fixed block and a moveable block. Each block is made of five metallic plates of a molybdenum and HEU alloy. Four cylindrical control rods, made of the same alloy, allows operation of the reactor in two modes: steady state power and pulsed. The reactor core is covered by a steel and boron carbide hood. The reactor core is shown in Figure 1.

Figure 1: View of the Caliban assembly

3 Irradiations

Two pulse irradiations were performed during the 2010 intercomparison exercise. The irradiation room is small and limited the number of positions and detector orientations. Complicating matters was a limitation on the number and size of phantoms allowed within the irradiation vault. As a result, both on-phantom and "in-air" irradiations were performed. A humanoid phantom filled with 2 g L^{-1} Na water was utilized during the second irradiation.

Following the irradiations the Caliban staff determined the total number of fissions for an irradiation and calculated the reference delivered doses at various distances. The 2010 reference doses are listed in Table 1 by distance from the assembly.

Table 1: Reference Doses for 2010 Intercomparison. The neutron dose, D_n includes contributions from both proton recoils and heavy charged particles. The incident gamma dose, D_γ, is a result of prompt photons emitted from the reactor.

Irradiation	Dist (m)	D_n (Gy)	D_γ (Gy)
1	2	5.1	0.7
1	3	2.6	0.5
1	4	1.7	0.4
2	2	7.2	1.0
2	2.5	5	0.8
2	4	2.4	0.6

During 2010 testing the following dosimeters and instruments were evaluated:

- Neutron thermoluminescent dosimeters (TLD)
- Photon TLD
- Activation foils
- Fixed nuclear accident dosimeter (FNAD)
- Alarming electronic dosimeters (photon)
- Sodium activation measurement instruments

The instruments used to measure sodium activation and TLD holder activity included the Ludlum Model 12 + 44-9, Ludlum Model 2224 + 43-89, and the Target Identifinder sodium iodide spectrometer.

The measurement locations are shown in Figure 2 for the first pulse and in Figure 3 for the second pulse. Table 2 describes the irradiation geometry for the locations used by Y-12.

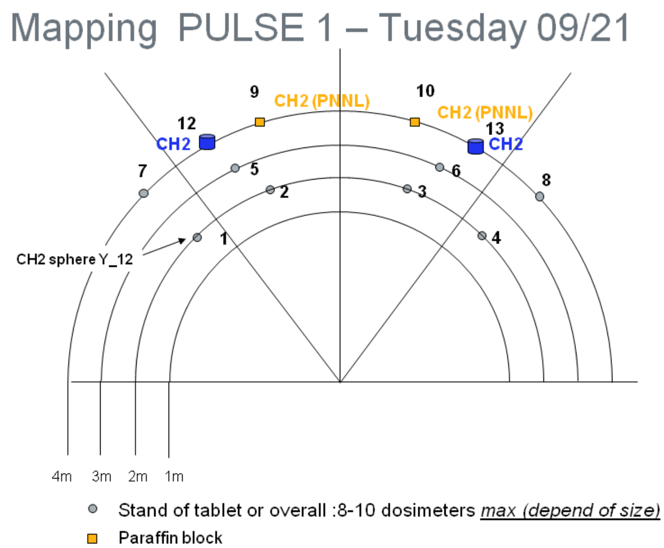

Figure 2: Irradiation locations for pulse 1. Irradiation geometries for locations used by Y-12 are listed in Table 2.

Electronic dosimeters (Model DMC-100) were located at the following positions: Shot 1: Position 3, Position 6, Position 7 Shot 2: Position 3, Position 4, Position 5, Position 8

Following irradiations measurements of activation foils, TLD holders, and biological samples (e.g. hair) were performed. Following pulse two, measurements of sodium activation in the humanoid phantom were performed.

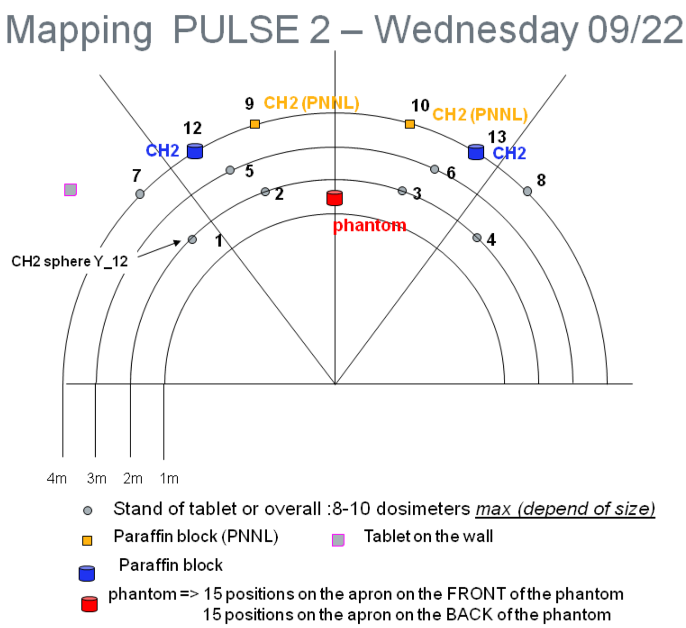

Figure 3: Irradiation locations for pulse 2. Irradiation geometries for locations used by Y-12 are listed in Table 2.

Table 2: Irradiation location description for 2010 Intercomparison.

Pulse	Location ID	Description
1	1	FNAD phantom
1	3	Metal plate
1	4	Metal plate
1	6	Metal plate
1	7	Metal plate
1	13	Polyethylene phantom
2	2	Apron on sodium phantom
2	3	Metal plate
2	4	Metal plate
2	5	Metal plate
2	13	Polyethylene phantom

4 Measurement Results

4.1 TLD Results

Following irradiation the TLD holders were opened and the fronts (which contain the filtration elements) were exchanged with un-irradiated holder fronts. The activated holder fronts were then counted using the portable instruments and mated with holder backs enclosing un-irradiated TLD cards. This served to limit the additional signal to TLDs from the activated filters and to allow for evaluation of the additional signal imparted to un-irradiated TLDs. The TLDs were returned to Y-12 where they were processed. Readings were corrected for background using control/transit TLDs.

The HBGT and neutron TLD results are listed in Table 3. Photon doses were calculated using the 2010 production HBGT algorithm. Neutron absorbed doses were calculated using spectral correction factors for the unshielded Health Physics Research Reactor (HPRR).

Table 3: Calculated Neutron and Photon Doses from TLDs.

Irr.	Dist. (m)	Neutron Dose (Gy)	Photon Dose (Gy)	Total Dose (Gy)
1	4	3.1	0.7	3.8
2	2.5	4.6	1.4	6.0
2	4	4.3	1.0	5.3

4.2 FNAD Results

The FNAD was irradiated at 2 m from the critical assembly during each excursions. The calculated neutron and photon doses are given in Table 4.

Table 4: Calculated FNAD neutron and photon doses

Irr.	Neutron Dose (Gy)	Photon Dose (Gy)	Total Dose (Gy)
1	3.1	1.0	4.1
2	4.4	1.3	5.7

4.3 Blood Sodium Measurements

Activated sodium measurements were performed 2.6, 23.3, and 28.1 hours after irradiation using the Identifinder and portable survey instruments. In the case of the Identifinder count times were 15 seconds, 30 seconds, and one minute. All counts indicated Na-24 with a confidence of 9 or 10. Measurements made using the Model 3 + 44-9 and Model 2224 + 43-89 instruments are given in Table 5. Also listed in Table 5 are the decay-corrected count rates as well as the average decay-corrected count rates for each instrument.

Table 5: Sodium activation measurements with portable instruments

Decay (hrs)	Model 43-89 CPM	Model 44-9 CPM
2.6	52543	15942
23.3	18384	5542
28.1	14598	4490
Decay Corrected		
2.6	59251	17978
23.3	53881	16243
28.1	53483	16452
Average	55538	16891

4.4 TLD Holder Measurements

Neutron and HBGT TLD holders were measured following irradiation using the Ludlum Model 3 + 44-9 and Ludlum Model 2224 + 43-89 instruments. The HBGT holder includes a copper foil while the neutron holder contains a cadmium foil. Results for the HBGT measurements were decay corrected using a half life of 12.7 hours. Neutron holder measurements were also decay corrected, but because of the multiple isotopes for cadmium activation two half lives were used. For measurements occurring within 6 hours of irradiation a half life of 24 hours was used while a half life of 9.25 hours was used for measurements occurring more than 6 hours after irradiation. The cadmium half lives were determined empirically. Results were corrected for background and decay and normalized to one Gy neutron dose. Conversions for neutron dose (Gy) per measured count rate (CPM) are listed in Table 6 for TLDs mounted on the front and back of a 30 cm wide, 20 cm high, and 10 cm deep polymethyl methacrylate (PMMA) phantom.

Table 6: TLD holder measurements with portable instruments

	Model 44-9		Model 43-89	
	Neutron CPM/Gy	HBGT CPM/Gy	Neutron CPM/Gy	HBGT CPM/Gy
Phantom front (Irr. 1)	739	182	464	255
Phantom front (Irr. 2)	739	185	472	250
Phantom back (Irr. 1)	376	145	346	223
Phantom back (Irr. 2)	483	90	297	158

4.5 Electronic Dosimeter Measurements

Electronic dosimeters (DMC-100) were irradiated at the locations listed in Table 7. Also given in Table 7 are the delivered and indicated photon doses.

Table 7: Electronic dosimeter results for photon doses

Irr.	Pos.	Dist. (m)	Delivered Dose (Gy)	Indicated Dose (Gy)
1	3	2	0.7	0.06
1	6	3	0.5	0.05
1	7	4	0.4	0.05
2	4	2	1	0.08
2	3	2	1	0.07
2	5	3	0.7	0.07
2	8	4	0.6	0.06

5 Discussion

A summary of the dose calculations is given in Table 8.

Table 8: Dose summary for 2009 calculated with each of the various dosimeters.

Irr.	Dist. (m)	Meas. Method	Neutron Dose (Gy)	Neutron Dose % Bias	Photon Dose (Gy)	Photon Dose % Bias
1	2	FNAD	3.1	-39	1.0	43
1	4	TLD	3.1	82	0.7	75
2	2	FNAD	4.4	-39	1.3	30
2	2.5	TLD	4.6	-8	1.4	75
2	4	TLD	4.3	79	1.0	67

The Identifinder performed well and the minimum detectable dose (MDD) values appear to coincide with those provided in Reference [1]. It is unfortunate that additional measurements could not be made at longer times post irradiation. Given the typical background count rates (50 cpm for the Model 44-9 and 125 cpm for the model 43-89) an approximate minimum detectable dose can be found. Assuming one minute background and sample counts, average CPM per Gy listed in Table 5, and various decay times, the minimum detectable neutron doses are listed in Table 9.

Table 9: Minimum detectable neutron dose using portable instruments.

t_{post} (Hr)	44-9 (Gy)	43-89 (Gy)	44-9 (Rad)	43-89 (Rad)
0	0.01	0.005	1	0.5
1	0.01	0.005	1	1
2	0.01	0.005	1	1
3	0.01	0.006	1	1
4	0.01	0.006	1	1
5	0.01	0.006	1	1
10	0.02	0.008	2	1
12	0.02	0.009	2	1
15	0.02	0.010	2	1
24	0.03	0.015	3	2
48	0.10	0.045	10	5

Measurements of TLD holder activation can provide useful information both as a means of providing an estimate of the delivered neutron dose and to estimate the filtration required on the

TLD readers before processing the TLD. Of course, doses estimated using activation (sodium or TLD holder) analysis are subject to large uncertainties.

The electronic dosimeters alarmed, but read about a factor of 10 low for each irradiation. Since they are not used for estimating doses this is not of concern, but this information may be useful if a preliminary estimate of dose is desired.

References

[1] K.G. Veinot and B.T. Gose. Technical Basis for Blood Sodium Activation Measurements at the Y-12 National Security Complex. Technical Report RCO/TBD-083, Y-12 National Security Complex, Oak Ridge, TN, 2009.